

NASA Technical Memorandum 80745

NASA-TM-80745 19790025683

Publications of the Planetary Biology Program for 1978 A Special Bibliography

NOT TO BE TAKEN FROM THIS ROOM

OCTOBER 1979

23 1979
LIBRARY OF THE
NASA
MANNING, VIRGINIA

NASA

NASA Technical Memorandum 80745

Publications of the Planetary
Biology Program for 1978
A Special Bibliography

Compiled by Linda G. Pleasant and Richard S. Young
NASA Office of Space Science
Washington, D.C.



National Aeronautics
and Space Administration

**Scientific and Technical
Information Branch**

1979

CONTENTS

INTRODUCTION	1
CHEMICAL EVOLUTION	3
ORGANIC GEOCHEMISTRY	9
LIFE DETECTION14
BIOLOGICAL ADAPTATION15
BIOINSTRUMENTATION18
PLANETARY ENVIRONMENTS19
ORIGIN OF LIFE20
APPENDIX: PRINCIPAL INVESTIGATORS27

INTRODUCTION

The Planetary Biology Program, within the Office of Space Science of the National Aeronautics and Space Administration, is the first and only integrated program to methodically investigate the planetary events which may have been responsible for, or related to, the origin, evolution, and distribution of life in the universe. Research supported by this program is divided into the seven areas listed below together with a statement of the principal objective of each research area.

Chemical Evolution - To understand how biologically significant organic molecules are synthesized under conditions presumed to have existed on the primitive Earth before the advent of life or which may presently exist on other planets.

Organic Geochemistry - To analyze terrestrial and extraterrestrial material for organic molecules, biological structures, and other clues to the origin(s) of life on this and other planets.

Life Detection - To develop and implement techniques to search for, detect, and characterize life and life-related molecules on this and other planets.

Biological Adaptation - To understand the adaptive mechanisms used by terrestrial organisms to survive and/or grow in environmental extremes approaching those on other planets.

Bioinstrumentation - To design, develop, and test prototype spaceflight instruments which will be used to detect and characterize life and life-related molecules on the surface and in the atmosphere of other planets.

Planetary Environments - To develop analytical techniques which measure environmental parameters on other planets which are relevant to the search for life.

Origin of Life - To identify the sequence of events leading from the putative complex organic milieu in the primordial terrestrial oceans to the origin of the first living systems.

The arrangement of references in this bibliography follows the division of research described. Articles are listed alphabetically by author under the research area with which they are most closely related. Only those publications which resulted from research supported by the Planetary Biology Program and which bear a 1978 publication date have been included. Abstracts, theses, and presentations are not included because of the preliminary and abbreviated nature of the former and the frequent difficulty of obtaining the latter.

Our intent in compiling this bibliography is twofold. First, we would like to provide the scientific community with an annual listing, beginning with 1975, of current publications resulting from research pursued under the auspices of NASA's Planetary Biology Program. Secondly, we hope to stimulate the exchange of information and ideas among scientists working in the different areas of the program. To facilitate the exchange process, we have identified, by asterisk, the author of each publication who is presently participating in the program. Current addresses for all principal investigators are given in the Appendix.

We wish to thank all the participants of the Planetary Biology Program for their cooperative response to our request for an enumeration of their 1978 publications.

Chemical Evolution

- Atreya, S.K., T.M. Donahue, and W.R. Kuhn*. 1978. Evolution of a nitrogen atmosphere on Titan. Science 201: 611-613.
- Biemann*, K. and J.E. Biller. 1978. Storage and retrieval of mass spectral data. In: R. Hirsch, ed. Principles of Experimentation and Data Analysis in Chemistry. Philadelphia: Franklin Institute Press.
- Biemann*, K., J.E. Biller, J. Oro, L.E. Orgel, A.O. Nier, D.M. Anderson, P.G. Simmonds, D. Flory, A.V. Diaz, and D. Rushneck. 1978. The search for organic and volatile inorganic compounds in two surface samples from the Chryse Planitia Region of Mars. In: C. Ponnampereuma, ed. Comparative Planetology. Proceedings of the College Park Colloquia on Chemical Evolution, College Park, Maryland, September 29 - October 1, 1976. New York: Academic Press.
- Bonner*, W.A. and R.M. Lemmon. 1978. Radiolysis, racemization and the origin of molecular asymmetry in the biosphere. Journal of Molecular Evolution 11: 95-99.
- Bonner*, W.A. and R.M. Lemmon. 1978. Radiolysis, racemization, and the origin of optical activity. Bioorganic Chemistry 7: 175-187.
- Bonner*, W.A., R.M. Lemmon, and H.P. Noyes. 1978. β Radiolysis of crystalline ^{14}C -labeled amino acids. Journal of Organic Chemistry 43: 522.
- Bonner*, W.A., M.A. Van Dort, and M.R. Yearian. 1978. Molecular chirality of life and intrinsic chirality of matter. Nature 271: 186.
- Des Marais*, D.J. 1978. Carbon, nitrogen and sulfur in Apollo 15, 16 and 17 rocks. In: Lunar and Planetary Science. Proceedings of the 9th Conference, Houston, Texas, March 1978. New York: Pergamon Press, pp. 2451-2467.
- Des Marais*, D.J. 1978. Variable-temperature cryogenic trap for the separation of gas mixtures. Analytical Chemistry 50: 1405-1406.
- Draganic, I., Z. Draganic, A. Shimoyama, and C. Ponnampereuma*. 1978. Evidence for amino acids in hydrolysates of compounds formed by ionizing radiations: II. Aqueous solutions of CH_3CN and $\text{C}_2\text{H}_5\text{CN}$. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 83-88.

- Draganic, Z., I. Draganic, A. Shimoyama, and C. Ponnampereuma*. 1978. Evidence for amino acids in hydrolysates of compounds formed by ionizing radiations: I. Aqueous solutions of HCN, NH₄CN, and NaCN. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 129-133.
- Epps, D.W., E. Sherwood, J. Eichberg, and J. Oro*. 1978. Cyanamide mediated syntheses under plausible primitive Earth conditions. V. The synthesis of phosphatidic acids. Journal of Molecular Evolution 11: 279-292.
- Etaix, E. and L.E. Orgel*. 1978. Phosphorylation of nucleosides in aqueous solution using trimetaphosphate: formation of nucleoside triphosphates. Journal of Carbohydrates Nucleosides Nucleotides 5(2): 91-110.
- Ferris*, J.P. 1978. Biopolymers and the origin of life. Chemistry 51(5): 14-16.
- Ferris*, J.P. and E.H. Edelson. 1978. Chemical evolution. 31. Mechanism of the condensation of cyanide to HCN oligomers. Journal of Organic Chemistry 43: 3989-3995.
- Ferris*, J.P., P.C. Joshi, E.H. Edelson, and J.G. Lawless. 1978. HCN: a plausible source of purines, pyrimidines and amino acids on the primitive Earth. Journal of Molecular Evolution 11: 293-311.
- Ferris*, J.P., P.C. Joshi, and J.G. Lawless. 1978. Chemical evolution: XXIX. Pyrimidines from hydrogen cyanide. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 187-191.
- Field, G.B., G.L. Verschuur, and C. Ponnampereuma*. 1978. Cosmic Evolution: An Introduction to Astronomy. Boston: Houghton Mifflin, 450 pp.
- Fitch, W.L., E.T. Everhart, and D.H. Smith¹. 1978. Characterization of carbon black adsorbates and artifacts formed during extraction. Analytical Chemistry 50: 2122-2126.
- Folsome*, C.E. Life: origin and evolution. In: The Origin of Life: Readings from Scientific American. San Francisco, W.H. Freeman and Co.

¹Levinthal, E.C., Principal Investigator

- Hobo, T., C. Ponnampetuma*, A.G. Hook, and B. Donn. 1978. Lower molecular weight hydrocarbon formation in an open flow system by Fischer Tropsch reaction. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 89-93.
- Khare, B.N., C. Sagan*, E.L. Bandurski, and B. Nagy. 1978. Ultra-violet-photoproducted organic solids synthesized under simulated Jovian conditions: molecular analysis. Science 199: 1199-1201.
- Lahav, N., D. White, and S. Chang*. 1978. Peptide formation in the prebiotic era: thermal condensation of glycine in fluctuating clay environments. Science 201: 67-69.
- Leach, W.W., D.W. Nooner, and J. Oro*. 1978. Abiotic synthesis of fatty acids. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 113-122.
- Loew, G.H., D.S. Berkowitz, and S. Chang*. 1978. Candidate interstellar molecules formed from ion-molecule reactions of NO. Astrophysical Journal 219: 458-466.
- Lohrmann, R. and L.E. Orgel*. 1978. Formation of P₁,P₂-dinucleoside 5'-pyrophosphates under potentially prebiological conditions. Journal of Molecular Evolution 11: 17-23.
- McLean, A.D., G.H. Loew, and D.S. Berkowitz¹. 1978. The barrier to linearity in the HNCO molecule. Journal of Molecular Spectroscopy 72: 430-437.
- McLean, A.D., G.H. Loew, and D.S. Berkowitz¹. 1978. HNO⁺ and NOH⁺ potential energy surfaces for the lowest two electronic states including the barrier to isomerization. Molecular Physics 36:1359-1372.
- Mizutani, H. and C. Ponnampetuma*. 1978. The effect of polynucleotides on the dimerization of glycine. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 273-277.
- Morss, D.A. and W.R. Kuhn*. 1978. Paleoatmospheric temperature structure. Icarus 33: 40-49.

¹Chang, S. Principal Investigator

- Negron-Mendoza, A. and C. Ponnampерума*. 1978. Interconversion of biologically important carboxylic acids by radiation. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/ Japan Scientific Societies Press, pp. 101-104.
- Nooner, D.W. and J. Oro*. 1978. Synthesis of fatty acids by a closed system Fischer-Tropsch process. Preprints, Division of Petroleum Chemistry, ACS 23: 624-631.
- Oro*, J., E. Sherwood, J. Eichberg, and D. Epps. 1978. Formation of phospholipids under primitive Earth conditions and the role of membranes in prebiological evolution. In: D.W. Deamer, ed. Light Transducing Membranes: Structure, Function, and Evolution. New York: Academic Press, pp. 1-19.
- Oyama*, V.I., B.J. Berdahl, F. Woeller, and M. Lehwalt. 1978. The chemical activities of the Viking biology experiments and the arguments for the presence of superoxides, peroxides, γ -Fe₂O₃ and carbon suboxide polymer in the Martian soil. In: R. Holmquist, ed. Life Sciences and Space Research, Volume 16. Proceedings of the Open Meeting of the Working Group on Space Biology of the Twentieth Plenary Meeting of COSPAR, Tel Aviv, Israel, June 7-18, 1977. New York: Pergamon Press, pp. 3-8.
- Pollock, G.E. and K.A. Kvenvolden¹. 1978. Stereochemistry of amino acids in surface samples of a marine sediment. Geochimica et Cosmochimica Acta 42: 1903-1905.
- Ponnampерума*, C. 1978. Comparative Planetology. Proceedings of the College Park Colloquia on Chemical Evolution, College Park, Maryland, September 29 - October 1, 1976. New York: Academic Press.
- Ponnampерума*, C. 1978. Cosmochemistry and the origin of life. In: W.O. Milligan, ed. Proceedings of the Robert A. Welch Foundation Conferences on Chemical Research. XXI. Cosmochemistry. Houston: Robert A. Welch Foundation, pp. 137-197.
- Ponnampерума*, C. 1978. The origin of life in the universe. EPOCA 1437: 48.
- Ponnampерума*, C. 1978. Our most remote ancestors. Chemistry 51(9): 6-12.
- Ponnampерума*, C. 1978. Prebiotic molecular evolution. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/ Japan Scientific Societies Press, pp. 67-81.

¹Des Marais, D.J., Principal Investigator

- Ponnamperuma*, C., A. Shimoyama, M. Yamada, T. Hobo, and R. Pal. 1978. Possible surface reactions on Mars: II. Implication for Viking labeled release results. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 45-49.
- Rushneck, D.R., A.V. Diaz, D.W. Howarth, J. Rampacek, K.W. Olson, W.D. Dencker, P. Smith, L. McDavid, A. Tomassian, M. Harris, K. Bulota, K. Biemann*, A. LaFleur, J.E. Biller, and T. Owen. 1978. Viking gas chromatograph-mass spectrometer. Review of Scientific Instruments 49(6): 817-834.
- Sagan*, C. 1978. Eavesdropping on galactic civilizations. Science 202: 374-375.
- Sherwood, E., D.W. Nooner, J. Eichberg, D.E. Epps, and J. Oro*. 1978. Prebiotic condensation reactions using cyanamide. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 105-111.
- Shimoyama, A., N. Blair, and C. Ponnamperuma*. 1978. Synthesis of amino acids under primitive Earth conditions in the presence of clay. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 95-99.
- Sleeper, H.L., R. Lohrmann, and L.E. Orgel*. 1978. Formation of the imidazolides of dinucleotides under potentially prebiotic conditions. Journal of Molecular Evolution 11: 87-93.
- Smith, D.H. and R.E. Carhart¹. 1978. Structure elucidation based on computer analysis of high and low resolution mass spectral data. In: M.L. Gross, ed. High Performance Mass Spectrometry: Chemical Applications. Washington, D.C.: American Chemical Society, pp. 325-347. (ACS Symposium Series, No. 70)
- Smith, D.H., W.J. Yeager, and T.C. Rindfleisch¹. 1978. Exchange of comments: analysis of complex volatile mixtures by a combined gas chromatography - mass spectrometry - computer system. Analytical Chemistry 50: 1585.
- Tornabene, T.G., R.S. Wolfe, W.E. Balch, G. Holzer, G.E. Fox, and J. Oro*, 1978. Phytanyl-glycerol ethers and squalenes in the archaeobacterium *Methanobacterium thermoautotrophicum*. Journal of Molecular Evolution 11: 259-266.

¹Levinthal, E.C., Principal Investigator

West, M.W., R.A. Koch, and S. Chang*. 1978. Chemical evolution and the origin of life. Bibliography supplement 1976. Origins of Life 9: 67-74.

Organic Geochemistry

- Awramik, S. and E.S. Barghoorn*. 1978. Bibliography of Precambrian paleontology and paleobiology. Harvard University Botanical Museum Leaflets 26: 65-175.
- Boon, J.J., J.W. de Leeuw, and A.L. Burlingame¹. 1978. Organic geochemistry of Walvis Bay diatomaceous ooze. III. Structural analysis of the monoenoic and polycyclic fatty acids. Geochimica et Cosmochimica Acta 42: 631-644.
- Boon, J.J., F.W. v.d. Meer, P.J.W. Schuyf, J.W. de Leeuw, P.A. Schenck, and A.L. Burlingame¹. 1978. Organic geochemical analyses of core samples from Site 362, Walvis Ridge, DSDP Leg 40. In: H.M. Bolli, W.B.F. Ryan, et al., eds. Initial Reports of the Deep Sea Drilling Project, Volume 40. Washington, D.C.: U.S. Government Printing Office, pp. 627-638.
- Bowes, G.W., M.J. Mulvihill, B.R.T. Simoneit, A.L. Burlingame¹, and R.W. Risebrough. 1978. Isolation and identification of chlorinated dibenzofurans from polychlorinated biphenyls (PCB) and from Yusho rice oil containing PCB. In: F. Cattabeni, A. Cavallaro, and G. Galli, eds. Dioxin: Toxicological and Chemical Aspects. Workshop on Dioxins, Milan, Italy, October 23-24, 1976. Jamaica, New York: Spectrum, pp. 79-98.
- Brassell, S.C., G. Eglinton, J.R. Maxwell, and R.P. Philp¹. 1978. Natural background of alkanes in the aquatic environment. In: O. Hutzinger, I.H. van Lelyveld, and B.C.J. Zoeteman, eds. Aquatic Pollutants: Transformation and Biological Effects. 2nd International Symposium on Aquatic Pollutants, Noordwijkerhout, Netherlands, September 26-28, 1977. New York: Pergamon Press, pp. 69-86.
- Brooks, P.W., J.R. Maxwell, and R.L. Patience¹. 1978. Stereochemical relationships between phytol and phytanic acid, dihydrophytol and C₁₈ ketone in Recent sediments. Geochimica et Cosmochimica Acta 42: 1175-1180.
- Burlingame¹, A.L., C.H.L. Shackleton, I. Howe, and O.S. Chizhov. 1978. Mass spectrometry. Analytical Chemistry Reviews 50: 346R-384R.

¹Calvin, M. and A.L. Burlingame, Co-Principal Investigators

- Cardoso, J.N., A.M.K. Wardroper, C.D. Watts, P.J. Barnes, J.R. Maxwell, G. Eglinton, D.G. Mound, and G.C. Speers¹. 1978. Preliminary organic geochemical analyses; Site 391, Leg 44 of the Deep Sea Drilling Project. In: W.E. Benson, R.E. Sheridan, et al., eds. Initial Reports of the Deep Sea Drilling Project, Volume 44. Washington, D.C.: U.S. Government Printing Office, pp. 617-623.
- Cardoso, J.N., C.D. Watts, J.R. Maxwell, R. Goodfellow, G. Eglinton, and S. Golubic¹. 1978. A biogeochemical study of the Abu Dhabi algal mats: a simplified ecosystem. Chemical Geology 23: 273-291.
- Chauvel, J.J. and J.W. Schopf*. 1978. Late Precambrian microfossils from Brioverian cherts and limestones of Brittany and Normandy, France. Nature 275: 640-642.
- Didyk, B.M., B.R.T. Simoneit, S.C. Brassell, and G. Eglinton¹. 1978. Organic geochemical indicators of palaeoenvironmental conditions of sedimentation. Nature 272: 216-222.
- Francis, S., E.S. Barghoorn*, and L. Margulis. 1978. On the experimental silicification of microorganisms. III. Implications of the preservation of the green prokaryotic alga *Prochloron* and other coccoids for interpretation of the microbial fossil record. Precambrian Research 7: 377-383.
- Francis, S., L. Margulis, and E.S. Barghoorn*. 1978. On the experimental silicification of microorganisms. II. On the time of appearance of eukaryotic organisms in the fossil record. Precambrian Research 6: 65-100.
- Games, L.M., J.M. Hayes*, and R.P. Gunsalus. 1978. Methane-producing bacteria: natural fractionations of the stable carbon isotopes. Geochimica et Cosmochimica Acta 42: 1295-1297.
- Hayes*, J.M., D.E. Matthews, and D.A. Schoeller. 1978. Effective deadtime of pulse-counting detector systems. Analytical Chemistry 50: 25-32.
- Ishiwatari, R., B.G. Rohrback, and I.R. Kaplan*. 1978. Hydrocarbon generation by thermal alteration of kerogen from different sediments. AAPG Bulletin 62: 687-692.
- Kerridge, J.F., I.R. Kaplan*, C.C. Kung, D.A. Winter, D.L. Friedman, and D.J. Des Marais. 1978. Light element geochemistry of the Apollo 12 site. Geochimica et Cosmochimica Acta 42: 391-402.

¹Calvin, M. and A.L. Burlingame, Co-Principal Investigators

- Khare, B.N., C. Sagan, E.L. Bandurski, and B. Nagy*. 1978. Ultraviolet-photoproducted organic solids synthesized under simulated Jovian conditions: molecular analysis. Science 199: 1199-1201.
- Knoll, A.H., E.S. Barghoorn*, and S.M. Awramik. 1978. New micro-organisms from the Aphebian Gunflint Iron Formation, Ontario. Journal of Paleontology 52: 976-992.
- Matthews, D.E., K.B. Denson, and J.M. Hayes*. 1978. Evaluation of the dynamic performance of selected ion monitoring mass spectrometers. Analytical Chemistry 50: 681-683.
- Matthews, D.E. and J.M. Hayes*. 1978. Isotope-ratio-monitoring gas chromatography: mass spectrometry. Analytical Chemistry 50: 1465-1473.
- Mazur, P., E.S. Barghoorn*, H.O. Halvorson, T.H. Jukes, I.R. Kaplan, and L. Margulis. 1978. Biological implications of the Viking mission to Mars. Space Science Reviews 22: 3-34.
- Patience, R.L., S.J. Rowland, and J.R. Maxwell¹. 1978. The effect of maturation on the configuration of pristane in sediments and petroleum. Geochimica et Cosmochimica Acta 42: 1871-1875.
- Peters, K.E., B.R.T. Simoneit, S. Brenner, and I.R. Kaplan*. 1978. Vitrinite reflectance-temperature determinations for intruded Cretaceous black shale in the Eastern Atlantic. In: D.F. Oltz, ed. Geochemistry: Low Temperature Metamorphism of Kerogen and Clay Minerals. Proceedings of the Symposium, Los Angeles, October 5, 1978. Los Angeles: Society of Economic Paleontologists and Mineralists, pp. 53-58.
- Philp, R.P., S. Brown, and M. Calvin¹. 1978. Isoprenoid hydrocarbons produced by thermal alteration of *Nostoc muscorum* and *Rhodospseudomonas spheroides*. Geochimica et Cosmochimica Acta 42: 63-68.
- Philp, R.P., S. Brown, and M. Calvin¹. 1978. Saponification of the insoluble organic residues from oil shales, algal oozes, and algae. Energy Sources 4(2): 113-123.
- Philp, R.P., S. Brown, M. Calvin¹, S. Brassell, and G. Eglinton. 1978. Hydrocarbon and fatty acid distributions in recently deposited algal mats at Laguna Guerrero, Baja California. In: W.E. Krumbein, ed. Environmental Biogeochemistry and Geomicrobiology. Volume 1: The Aquatic Environment. Ann Arbor, Michigan: Ann Arbor Science Publishers, pp. 255-270.

¹Calvin, M. and A.L. Burlingame, Co-Principal Investigators

- Philp, R.P., M. Calvin¹, S. Brown, and E. Yang. 1978. Organic geochemical studies on kerogen precursors in recently deposited algal mats and oozes. Chemical Geology 22: 207-231.
- Rohrback², B.G. 1978. Hydrocarbon generation during laboratory thermal alteration experiments. In: D.F. Oltz, ed. Geochemistry: Low Temperature Metamorphism of Kerogen and Clay Minerals. Proceedings of the Symposium, Los Angeles, October 5, 1978. Los Angeles: Society of Economic Paleontologists and Mineralists, pp. 47-51.
- Rohrback, B.G. and I.R. Kaplan*. 1978. The effects of source on production of low molecular weight hydrocarbons. In: D.F. Oltz, ed. Geochemistry: Low Temperature Metamorphism of Kerogen and Clay Minerals. Proceedings of the Symposium, Los Angeles, October 5, 1978. Los Angeles: Society of Economic Paleontologists and Mineralists, pp. 13-17.
- Schopf*, J.W. 1978. The evolution of the earliest cells. Scientific American 239(3): 110-134.
- Schopf*, J.W. 1978. On palaeobotany, palynology and related studies in China, 1978. International Organization of Palaeobotany Newsletter 7: 10-22.
- Schopf*, J.W. 1978. Stromatolites. In: M.R. Walter, ed. Sedimentary Geology. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 316-318. (Developments in Sedimentology, Vol. 20)
- Schopf*, J.W. and K.N. Prasad. 1978. Microfossils in *Collenia*-like stromatolites from the Proterozoic Vempalle Formation of the Cuddapah Basin, India. Precambrian Research 6: 347-366.
- Simoneit, B.R.T., S. Brenner, K.E. Peters, and I.R. Kaplan*. 1978. Thermal alteration of Cretaceous black shale by basaltic intrusions in the Eastern Atlantic. Nature 273: 501-504.
- Smith*, G.G., K.M. Williams, and D.M. Wonnacott. 1978. Factors affecting the rate of racemization of amino acids and their significance to geochronology. Journal of Organic Chemistry 43: 1-5.
- Straub, K., T. Meehan, H. Kambara, A.L. Burlingame¹, and S. Evans. 1978. Field desorption/collision-induced dissociation (FD/CID) mass spectrometry of the free benzo[a]pyrene diol epoxide adducts of DNA. In: A.G. Harrison, ed. Mass Spectrometry and Allied Topics. Proceedings of the 26th Annual Conference, St. Louis, Missouri, May 1978. St. Louis: American Society for Mass Spectrometry, pp. 499-501.

¹Calvin, M. and A.L. Burlingame, Co-Principal Investigators

²Kaplan, I.R., Principal Investigator

- Stuermer, D.H., K.E. Peters, and I.R. Kaplan*. 1978. Source indicators of humic substances and proto-kerogen. Stable isotope ratios, elemental compositions and electron spin resonance spectra. Geochimica et Cosmochimica Acta 42: 989-997.
- Thompson, S. and G. Eglinton¹. 1978. The fractionation of a Recent sediment for organic geochemical analysis. Geochimica et Cosmochimica Acta 42: 199-207.
- Tibbetts, P.J.C., J.R. Maxwell, and S. Golubic¹. 1978. Carotenoids in an algal mat and ooze from Laguna Mormona, Baja California. In: W.E. Krumbein, ed. Environmental Biogeochemistry and Geomicrobiology. Volume 1: The Aquatic Environment. Ann Arbor, Michigan: Ann Arbor Science Publishers, pp. 271-280.
- Vogler, E.A. and J.M. Hayes*. 1978. The synthesis of carboxylic acids with carboxyl carbons of precisely known stable isotopic composition. International Journal of Applied Radiation and Isotopes 29: 297-200.
- Vogler, E.A., R.L. Stein, and J.M. Hayes*. 1978. Mechanism of formation of Grignard reagents. Journal of the American Chemical Society 100: 3163-3166.
- Wardroper, A.M.K. and J.R. Maxwell¹. 1978. Sterols of a diatomaceous ooze from Walvis Bay. Steroids 32: 203-221.
- Wilson, D.M., A.L. Burlingame¹, S. Evans, T. Cronholm, and J. Sjövall. 1978. Detection and quantification of stable isotope incorporation by high resolution mass spectrometry and $^{13}\text{C}\{^2\text{H}, ^1\text{H}\}$ nuclear magnetic resonance difference spectroscopy. Utilization of carbon and hydrogen atoms of ethanol in the biosynthesis of bile acids. In: T.A. Baillie, ed. Stable Isotopes: Applications in Pharmacology, Toxicology and Clinical Research. Proceedings of an International Symposium on Stable Isotopes, London, January 3-4, 1977. London: Macmillan, pp. 205-216.
- Zumberge, J.E., A.C. Sigleo, and B. Nagy*. 1978. Molecular and elemental analyses of the carbonaceous matter in the gold and uranium bearing Vaal Reef carbon seams, Witwatersrand Sequence. Minerals Science and Engineering 10: 223-246.

¹Calvin, M. and A.L. Burlingame, Co-Principal Investigators

Life Detection

Horwitz, A.H. and L.E. Casida*, Jr. 1978. Effects of magnesium, calcium, and serum on reversion of stable L-forms. Journal of Bacteriology 136: 565-569.

Horwitz, A.H. and L.E. Casida*, Jr. 1978. Survival and reversion of a stable L form in soil. Canadian Journal of Microbiology 24: 50-55.

Levin*, G.V., P.A. Straat, and W.D. Benton. 1978. Color and feature changes at Mars Viking Lander site. Journal of Theoretical Biology 75: 381-390.

Biological Adaptation

- Broeze, R.J., C.J. Solomon, and D.H. Pope*. 1978. Effects of low temperature on in vivo and in vitro protein synthesis in *Escherichia coli* and *Pseudomonas fluorescens*. Journal of Bacteriology 134: 861-874.
- DeRosa, F., D. Haber, C. Williams, and L. Margulis*. 1978. Inhibitory effects of the herbicide trifluralin on the establishment of the clover root nodule symbiosis. Cytobios 21: 37-43.
- Francis, S., E.S. Barghoorn, and L. Margulis*. 1978. On the experimental silicification of microorganisms. III. Implications of the preservation of the green prokaryotic alga *Prochloron* and other coccoids for interpretation of the microbial fossil record. Precambrian Research 7: 377-383.
- Francis, S., L. Margulis*, and E.S. Barghoorn. 1978. On the experimental silicification of microorganisms. II. On the time of appearance of eukaryotic organisms in the fossil record. Precambrian Research 6: 65-100.
- Jost, P.C., D.A. McMillen, W.D. Morgan, and W. Stoeckenius*. 1978. Lipid-protein interactions in the purple membrane. In: D.W. Deamer, ed. Light Transducing Membranes: Structure, Function, and Evolution. New York: Academic Press, pp. 141-155.
- Lozier, R.H., Q. Chae, P.C. Mowery, and W. Stoeckenius*. 1978. Flash photolysis studies of bacteriorhodopsin formed at extreme low pH. In: S.R. Caplan and M. Ginzburg, eds. Energetics and Structure of Halophilic Microorganisms. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 297-302.
- Lozier, R.H., W. Niederberger, M. Ottolenghi, G. Sivorinovsky, and W. Stoeckenius*. 1978. On the photocycles of light- and dark-adapted bacteriorhodopsin. In: S.R. Caplan and M. Ginzburg, eds. Energetics and Structure of Halophilic Microorganisms. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 123-141.
- Margulis*, L. and J.E. Lovelock. 1978. The biota as the ancient and modern modulator of the Earth's atmosphere. Pure and Applied Geophysics 116: 239-243.
- Margulis*, L., G. Thorington, B. Berger, and J. Stolz. 1978. Endosymbiotic bacteria associated with the intracellular green algae of *Hydra viridis*. Current Microbiology 1: 227-232.
- Margulis*, L., L. To, and D. Chase. 1978. Microtubules in prokaryotes. Science 200: 1118-1123.

- Mazur, P., E.S. Barghoorn, H.O. Halvorson, T.H. Jukes, I.R. Kaplan, and L. Margulis*. 1978. Biological implications of the Viking mission to Mars. Space Science Reviews 22: 3-34.
- Stoeckenius*, W. 1978. Bacteriorhodopsin. In: R.K. Clayton and W.R. Sistrom, eds. The Photosynthetic Bacteria. New York: Plenum Press, pp. 571-592.
- Stoeckenius*, W. 1978. Bioenergetic mechanisms in halobacteria. In: S.R. Caplan and M. Ginzburg, eds. Energetics and Structure of Halophilic Microorganisms. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 185-200.
- Stoeckenius*, W. 1978. Speculations about the evolution of halobacteria and of chemiosmotic mechanisms. In: D.W. Deamer, ed. Light Transducing Membranes: Structure, Function, and Evolution. New York: Academic Press, pp. 127-139.
- Tindall, D.R., J.H. Yopp*, D.M. Miller, and W.E. Schmid. 1978. Physico-chemical parameters governing the growth of *Aphanothece halophytica* (Chroococcales) in hypersaline media. Phycologia 17: 179-185.
- To, L. and L. Margulis. 1978. Ancient locomotion: prokaryotic motility systems. International Review of Cytology 54: 267-293.
- To, L., L. Margulis, and A.T.W. Cheung. 1978. Pillotinas: distribution and behavior of large spirochaetes symbiotic in termites. Microbios 22: 103-134.
- Venable, W.C., D.M. Miller, and J.H. Yopp*. 1978. Pulsed NMR study in an obligately halophilic blue-green alga. Physiological Chemistry and Physics Journal 10: 405-414.
- Watson, A., J.E. Lovelock, and L. Margulis*. 1978. Methanogenesis, fires and the regulation of atmospheric oxygen. BioSystems 10: 293-298.
- Wedler*, F.C. 1978. Properties and regulation of thermophilic glutamine synthetases. In: S.M. Friedman, ed. Biochemistry of Thermophily. New York: Academic Press, pp. 325-343.
- Wedler*, F.C., R.M. Kenney, A.E. Ashour, and J. Carfi. 1978. Two regulatory isozymes of glutamine synthetase from *Bacillus caldolyticus* on extreme thermophile. Biochemical and Biophysical Research Communications 81: 122-126.
- Whittaker, R.H. and L. Margulis*. 1978. Protist classification and the kingdoms of organisms. BioSystems 10: 3-18.

- Wong, B.S., D.M. Miller, and J.H. Yopp*. 1978. Proton pulsed NMR study on the cell constituents of *Aphanothece halophytica*, a blue-green alga. In: P.F. Agris, ed. Biomolecular Structure and Function. New York: Academic Press, pp. 239-245.
- Yopp*, J.H., D.M. Miller, and D.R. Tindall. 1978. Regulation of intracellular water potential in the halophilic blue-green alga *Aphanothece halophytica* (Chroococcales). In: S.R. Caplan and M. Ginzburg, eds. Energetics and Structure of Halophilic Microorganisms. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 619-624.
- Yopp*, J.H., D.R. Tindall, D.M. Miller, and W.E. Schmid. 1978. Isolation, purification and evidence for a halophilic nature of the blue-green alga *Aphanothece halophytica* Frey (Chroococcales). Phycologia 17: 172-178.

Bioinstrumentation

No publications.

Planetary Environments

Stabekis, P. and D.L. DeVincenzi*. 1978. Planetary protection guidelines for outer planet missions. In: R. Holmquist, ed. Life Sciences and Space Research, Volume 16. Proceedings of the Open Meeting of the Working Group on Space Biology of the Twentieth Plenary Meeting of COSPAR, Tel Aviv, Israel, June 7-18, 1977. New York: Pergamon Press, pp. 39-44.

Woeller*, F.H. and G.E. Pollock. 1978. Synthesis of porous polyaromatic column packings for GC analysis of extraterrestrial atmospheres. Journal of Chromatographic Science 16: 137-140.

Origin of Life

- Armstrong, D.W., R. Seguin, C.J. McNeal, R.D. Macfarlane, and J.H. Fendler¹. 1978. Spontaneous polypeptide formation from amino acyl adenylates in surfactant aggregates. Journal of the American Chemical Society 100: 4605-4606.
- Belliveau, J.W. and J.K. Lanyi*. 1978. Calcium transport in *Halobacterium halobium* envelope vesicles. Archives of Biochemistry and Biophysics 186: 98-105.
- Bogomolni, R.A., L. Stubbs, and J.K. Lanyi*. 1978. Illumination-dependent changes in the intrinsic fluorescence of bacteriorhodopsin. Biochemistry 17: 1037-1041.
- Bradley², P.M. 1978. Production of enucleated plant protoplasts of *Allium cepa*. Plant Science Letters 13: 287-290.
- Chen, M.C., R. Giege, R.C. Lord, and A. Rich*. Raman spectra of ten aqueous transfer RNAs and 5S RNA. Conformational comparison with yeast phenylalanine transfer RNA. Biochemistry 17: 3134-3138.
- Coeckelenbergh, Y., J. Hart, R.D. MacElroy, and R. Rein*. 1978. Computer display and manipulation of biological molecules. Computers and Graphics 3: 9-16.
- Coeckelenbergh, Y., R. Rein*, and R.D. MacElroy. 1978. Ames Interactive Molecular Model Building System: a 3-D computer modelling system applied to the study of the origin of life. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 255-264.
- Dayhoff*, M.O., L.T. Hunt, W.C. Barker, R.M. Schwartz, and B.C. Orcutt. 1978. Protein Segment Dictionary 78. Washington, D.C.: National Biomedical Research Foundation, 470 pp.
- Dayhoff*, M.O. and R.M. Schwartz. 1978. Evolution of prokaryotes inferred from sequences. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 323-342.

¹Nagyvary, J., Principal Investigator

²Danielli, J.F., Principal Investigator

- Dayhoff*, M.O. and R.M. Schwartz. 1978. Evolution of early life inferred from protein and ribonucleic acid sequences. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 547-560.
- Egan, J.T., S. Nir, R. Rein*, and R. MacElroy*. 1978. Configurations of base-pair complexes in solutions. International Journal of Quantum Chemistry: Quantum Biology Symposium 5: 433-440.
- Eirich*, F.R. 1978. Sequence trends in macromolecular syntheses. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 121-128.
- Fox*, S.W. 1978. The origin and nature of protolife. In: W.H. Heidcamp, ed. The Nature of Life. Baltimore: University Park Press, pp. 23-92.
- Fox*, S.W., T. Adachi, W. Stillwell, Y. Ishima, and G. Baumann. 1978. Photochemical synthesis of ATP: protomembranes and protometabolism. In: D.W. Deamer, ed. Light Transducing Membranes: Structure, Function, and Evolution. New York: Academic Press, pp. 61-75.
- Fox*, S.W., J.W. Frankenfeld, D. Romsos, D.M. Robinson, and S.A. Miller. 1978. Chemical synthesis of nutrients. In: M. Milner, N.S. Scrimshaw, and D.I.C. Wang, eds. Protein Resources and Technology: Status and Research Needs. Westport, Connecticut: AVI Publishing Company, pp. 569-583.
- Fox*, S.W., P. Melius, and T. Nakashima. 1978. N-Terminal pyroglutamyl residues in proteins and thermal peptides. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 111-120.
- Grote, J.R., R.M. Syren, and S.W. Fox*. 1978. Effect of products from heated amino acids on conductance in lipid bilayer membranes and non-aqueous solvents. BioSystems 10: 287-292.
- Helgerson, S.L. and J.K. Lanyi*. 1978. Methionine transport in *Halobacterium halobium* vesicles: noncompetitive, asymmetric inhibition by L-cysteine. Biochemistry 17: 1042-1046.
- Holmquist¹, R. 1978. The augmentation algorithm and molecular phylogenetic trees. Journal of Molecular Evolution 12: 17-24.

¹Jukes, T.H., Principal Investigator

- Holmquist¹, R. 1978. Evaluation of compositional nonrandomness in proteins. Journal of Molecular Evolution 11: 349-360.
- Holmquist¹, R. 1978. A measure of the denseness of a phylogenetic network. Journal of Molecular Evolution 11: 225-231.
- Holmquist¹, R. 1978. The REH theory of protein and nucleic acid divergence: a retrospective update. Journal of Molecular Evolution 11: 361-374.
- Jukes*, T.H. 1978. The amino acid code. In: A. Meister, ed. Advances in Enzymology, Volume 47. New York: John Wiley & Sons, pp. 375-432.
- Jukes*, T.H. 1978. Codons and nearest-neighbor nucleotide pairs in mammalian messenger RNA. Journal of Molecular Evolution 11: 121-127.
- Jukes*, T.H. 1978. Neutral changes during divergent evolution of hemoglobins. Journal of Molecular Evolution 11: 267-269.
- Kapovits, I. and J. Nagyvary*. 1978. Mechanistic possibilities in prebiotic thiophosphate chemistry. Journal of Molecular Evolution 11: 25-33.
- Lanyi*, J.K. 1978. Coupling of aspartate and serine transport to the transmembrane electrochemical gradient for sodium ions in *Halobacterium halobium*. Translocation stoichiometries and apparent cooperativity. Biochemistry 17: 3011-3018.
- Lanyi*, J.K. 1978. Light energy conversion in *Halobacterium halobium* cell envelope vesicles. In: D.W. Deamer, ed. Light Transducing Membranes: Structure, Function, and Evolution. New York: Academic Press, pp. 157-165.
- Lanyi*, J.K. 1978. Transport of cations and amino acids in *Halobacterium halobium*. In: S.R. Caplan and M. Ginzburg, eds. Energetics and Structure of Halophilic Microorganisms. Amsterdam: Elsevier/North-Holland Biomedical Press, pp. 415-426.
- Levi, N. and J.G. Lawless*. 1978. Selective photodestruction of α -amino acids. Analytical Biochemistry 90: 796-801.
- MacElroy, R.D., Y. Coeckelenbergh, and R. Rein*. 1978. An approach to the origin of self-replicating systems: I. Intermolecular interactions. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 249-254.

¹Jukes, T.H., Principal Investigator

- MacElroy, R.D., Y. Coeckelenbergh, and R. Rein*. 1978. Computerized molecular modelling systems and intermolecular interactions. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 129-134.
- MacElroy, R.D., R. Rein*, and Y. Coeckelenbergh. 1978. Macromolecular simulations as an approach to the study of the origins of self-replicating systems. BioSystems 9: 111-119.
- Magrum, L.J., K.R. Luehrsen, and C.R. Woese*. 1978. Are extreme halophiles actually "bacteria"? Journal of Molecular Evolution 11: 1-8.
- Miller¹, J.E. 1978. A proposal for the genetic manipulation of plant metabolism. Journal of Theoretical Biology 74: 153-154.
- Mirzabekov, A.D. and A. Rich*. 1978. The possible role of asymmetric neutralization of DNA by histones in folding nucleosomal DNA. Doklady Akademii Nauk SSSR 243: 1581-1584.
- Ornstein, R.L., R. Rein*, D.L. Breen, and R.D. MacElroy*. 1978. An optimized potential function for the calculation of nucleic acid interaction energies. I. Base stacking. Biopolymers 17: 2341-2360.
- Paecht-Horowitz², M. 1978. Clay catalyzed polymerization of amino acid adenylates and its relationship to biochemical reactions. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 289-295.
- Paecht-Horowitz², M. 1978. The influence of various cations on the catalytic properties of clays. Journal of Molecular Evolution 11: 101-107.
- Quigley, G.J., M.M. Teeter, and A. Rich*. 1978. Structural analysis of spermine and magnesium ion binding to yeast phenylalanine transfer RNA. Proceedings of the National Academy of Sciences of the U.S.A. 75: 64-68.
- Rein*, R., R. Garduno, Y. Coeckelenbergh, and R.D. MacElroy. 1978. The nature of the genetic code in relation to base substitution. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 135-139.

¹Danielli, J.F., Principal Investigator

²Eirich, F., Principal Investigator

- Rein*, R., R. Garduno, J.T. Egan, S. Colombano, Y. Coeckelenbergh, and R.D. MacElroy. 1978. A model for stereospecific recognition of purines as an element of a DNA polypeptide recognition code. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 265-272.
- Rein*, R., S. Nir, K. Haydock, and R.D. MacElroy*. 1978. Interactive computer graphics for bio-stereochemical modelling. Proceedings of the Indian Academy of Sciences 87A: 95-113.
- Rein*, R., R.L. Ornstein, and R.D. MacElroy*. 1978. Nucleic acid constituent interactions. Proceedings of the Indian Academy of Sciences 87B: 135-145.
- Rein*, R., P.K. Srivastava, V. Kothekar, S. Gupta, S. Dutta, R.K. Mishra, and R.D. MacElroy. 1978. Stereochemical and dynamic aspects of genetic recombination. Contributions to Microbiology and Immunology 6(21): 1-6.
- Rich*, A. 1978. Transfer RNA: three-dimensional structure and biological function. Trends in Biochemical Sciences 3: 34-37.
- Rich*, A. and S.H. Kim. 1978. The three-dimensional structure of transfer RNA. Scientific American 238(1): 52-62.
- Rich*, A. and G.J. Quigley. 1978. Molecular structure and biological function of transfer RNA. In: P.W. Kent, ed. New Approaches to Genetics: Developments in Molecular Genetics. London: Oriel Press, pp. 100-125.
- Rohlfing*, D.L. and M.A. Saunders. 1978. Evolutionary processes possibly limiting the kinds of amino acids in protein to twenty: a review. Journal of Theoretical Biology 71: 487-503.
- Schwartz, R.M. and M.O. Dayhoff*. 1978. Detection of distant relationships based on point mutation data. In: H. Matsubara and T. Yamanaka, eds. Evolution of Protein Molecules. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 1-16.
- Schwartz, R.M. and M.O. Dayhoff*. 1978. Origins of prokaryotes, eukaryotes, mitochondria, and chloroplasts. Science 199: 395-403.
- Schwartz, R.M. and M.O. Dayhoff*. 1978. An outline of biological evolution based on macromolecular sequences. In: C. Ponnamperna, ed. Comparative Planetology. Proceedings of the College Park Colloquia on Chemical Evolution, College Park, Maryland, September 29 - October 1, 1976. New York: Academic Press, pp. 225-242.

- Schwartz, R.M. and M.O. Dayhoff*. 1978. The point mutation process in proteins. In: H. Noda, ed. Origin of Life. Proceedings of the Second ISSOL Meeting the Fifth ICOL Meeting. Tokyo: Center for Academic Publications Japan/Japan Scientific Societies Press, pp. 457-469.
- Wang, A.H.J., J. Nathans, G. van der Marel, J.H. van Boom, and A. Rich*. 1978. Molecular structure of a double helical DNA fragment intercalator complex between deoxy CpG and a terpyridine platinum compound. Nature 276: 471-474.
- Wang, A.H.J., M.L. Sherman, and A. Rich*. 1978. A crystallographic investigation of citrate synthase from pig and chicken heart muscle. Biochemical and Biophysical Research Communications 82: 150-156.
- Weber, A.L. and J.C. Lacey*, Jr. 1978. Genetic code correlations: amino acids and their anticodon nucleotides. Journal of Molecular Evolution 11: 199-210.
- Woese*, C.R. and G.E. Fox. 1978. Methanogenic bacteria. Nature 273: 101.
- Woese*, C.R., L.J. Magrum, and G.E. Fox. 1978. Archaeobacteria. Journal of Molecular Evolution 11: 245-252.
- Zielinski, T.J., D.L. Breen, K. Haydock, R. Rein*, and R.D. MacElroy*. 1978. Optimum geometries and relative energies for guanine, the imino-enol tautomer of guanine, the enol tautomer of guanine, adenine, and the imino tautomer of adenine as found by the MINDO/2 SCF MO method. International Journal of Quantum Chemistry: Quantum Biology Symposium 5: 355-365.
- Zielinski, T.J., D.L. Breen, and R. Rein*. 1978. A MINDO/3 study of some hydrogen-bonded systems. Journal of the American Chemical Society 100: 6266.
- Zielinski, T.J. and R. Rein*. 1978. Optimum geometries and relative energies for cytosine, thymine, uracil, the imino tautomer of cytosine, the enol tautomer of thymine, and the enol tautomer of uracil by the MINDO/2 SCF MO method. International Journal of Quantum Chemistry 14: 851-860.

APPENDIX: PRINCIPAL INVESTIGATORS

Professor Elso E. Barghoorn
The Biological Laboratories
Harvard University
16 Divinity Avenue
Cambridge, Massachusetts 02138

Professor Ralph S. Becker
Department of Chemistry
University of Houston
Houston, Texas 77004

Professor Klaus Biemann
Department of Chemistry
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Professor William A. Bonner
Department of Chemistry
Stanford University
Stanford, California 94305

Dr. A.L. Burlingame
Biomedical and Environmental Mass
Spectrometry Resource
Space Sciences Laboratory
University of California
Berkeley, California 94720

Professor Melvin Calvin
Laboratory of Chemical Biodynamics
Department of Chemistry
University of California
Berkeley, California 94720

Mr. Glenn C. Carle
Ames Research Center
Code LPD
Moffett Field, California 94035

Professor L.E. Casida, Jr.
Department of Microbiology and Cell
Biology
College of Science
The Pennsylvania State University
University Park, Pennsylvania 16802

Dr. Sherwood Chang
Ames Research Center
Code LPE
Moffett Field, California 94035

Professor John R. Cronin
Department of Chemistry
Arizona State University
Tempe, Arizona 85281

Professor James F. Danielli
Department of Life Sciences
Worcester Polytechnic Institute
Worcester, Massachusetts 01609

Mr. R. Day
TRW Systems, Incorporated
One Space Park
Redondo Beach, California 90278

Professor Margaret O. Dayhoff
National Biomedical Research Foundation
Georgetown University Medical Center
3900 Reservoir Road, N.W.
Washington, D.C. 20007

Dr. David J. Des Marais
Ames Research Center
Code LX
Moffett Field, California 94035

Dr. Donald L. DeVincenzi
Ames Research Center
Code LP
Moffett Field, California 94035

Professor Frederick R. Eirich
Department of Chemistry
Polytechnic Institute of New York
333 J Street
Brooklyn, New York 11201

Professor James P. Ferris
Department of Chemistry
School of Science
Rensselaer Polytechnic Institute
Troy, New York 12181

Professor Clair E. Folsome
Laboratory for Exobiology
Department of Microbiology
University of Hawaii at Manoa
2538 The Mall
Honolulu, Hawaii 96822

Assistant Professor George E. Fox
Department of Biophysical Sciences
University of Houston
Houston, Texas 77004

Dr. Sidney W. Fox, Director
Institute for Molecular and Cellular
Evolution
University of Miami
521 Anastasia
Coral Gables, Florida 33134

Professor E. Imre Friedmann
Department of Biological Science
Florida State University
Tallahassee, Florida 32306

Dr. Arthur Furst
Dean, Graduate Division
University of San Francisco
San Francisco, California 94117

Professor Stjepko Golubic
Department of Biology
Boston University
Boston, Massachusetts 02215

Professor William A. Guillory
Department of Chemistry
University of Utah
Salt Lake City, Utah 84112

Professor John M. Hayes
Department of Chemistry
Indiana University
Bloomington, Indiana 47405

Mr. Lawrence I. Hochstein
Ames Research Center
Code LPB
Moffett Field, California 94035

Professor Norman H. Horowitz
Department of Biology
California Institute of Technology
Pasadena, California 91109

Professor Jerry Hubbard
School of Biology
Georgia Institute of Technology
Atlanta, Georgia 30332

Dr. Richard D. Johnson
Ames Research Center
Code LB
Moffett Field, California 94035

Professor Thomas H. Jukes
Space Sciences Laboratory
University of California
Berkeley, California 94720

Professor Ian R. Kaplan
Department of Biology
Institute of Geophysics and Planetary
Physics
University of California
Los Angeles, California 90024

Dr. Harold P. Klein
Ames Research Center
Code L
Moffett Field, California 94035

Professor William R. Kuhn
Department of Atmospheric & Oceanic
Science
College of Engineering
University of Michigan
Ann Arbor, Michigan 48109

Associate Professor James C. Lacey, Jr.
Laboratory of Molecular Biology
University of Alabama School of Medicine
University Station
Birmingham, Alabama 35294

Mr. Janos K. Lanyi
Ames Research Center
Code LPB
Moffett Field, California 94035

Mr. James G. Lawless
Ames Research Center
Code LPE
Moffett Field, California 94035

Dr. Edward R. Leadbetter
Department of Biology
Amherst College
Amherst, Massachusetts 01002

Dr. Gilbert V. Levin
Biospherics Incorporated
4928 Wyaconda Road
Rockville, Maryland 20852

Dr. Elliott C. Levinthal
Department of Genetics
Stanford University School of Medicine
Stanford, California 94305

Dr. Gilda H. Loew
Stanford University
Stanford, California 94035

Associate Professor Russell E. MacDonald
Section of Biochemistry, Molecular and
Cell Biology
Division of Biological Sciences
Wing Hall
Cornell University
Ithaca, New York 14853

Dr. Robert D. MacElroy
Ames Research Center
Code LPB
Moffett Field, California 94035

Associate Professor Lynn Margulis
Department of Biology
Boston University
2 Cummington Street
Boston, Massachusetts 02215

Mr. Joe Martin
Martin Marietta Corporation
Denver Division
P.O. Box 179
Denver, Colorado 80201

Professor Bartholomew Nagy
Department of Geosciences
Laboratory of Organic Geochemistry
University of Arizona
Tucson, Arizona 85721

Dr. Joseph Nagyvary
Department of Biochemistry and Biophysics
Texas A&M University
College Station, Texas 77843

Dr. Leslie E. Orgel
Salk Institute for Biological Studies
P.O. Box 1809
San Diego, California 92112

Professor John Oro
Laboratory of Biomolecular Analysis
Department of Biophysical Sciences
University of Houston
Houston, Texas 77004

Mr. Vance I. Oyama
Ames Research Center
Code LPD
Moffett Field, California 94035

Mr. Glenn E. Pollock
Ames Research Center
Code LPE
Moffett Field, California 94035

Professor Cyril Ponnampерuma
Laboratory of Chemical Evolution
Department of Chemistry
University of Maryland
College Park, Maryland 20742

Associate Professor Daniel H. Pope
Department of Biology
Rensselaer Polytechnic Institute
Troy, New York 12181

Dr. Richard Radmer
Martin Marietta Laboratories
Martin Marietta Corporation
1450 South Rolling Road
Baltimore, Maryland 21227

Dr. Robert Rein
New York State Department of
Health
Roswell Park Memorial Institute
666 Elm Street
Buffalo, New York 14263

Professor Alexander Rich
Department of Biology
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Associate Professor Edward M. Ripley
Department of Geology
Indiana University
1005 East Tenth Street
Bloomington, Indiana 47401

Professor Duane L. Rohlfsing
Department of Biology
University of South Carolina
Columbia, South Carolina 29208

Professor Carl E. Sagan
Laboratory for Planetary Studies
Center for Radiophysics and Space
Research
Cornell University
Ithaca, New York 14853

Professor J. William Schopf
Department of Earth and Space Sciences
3806 Geology Building
University of California
Los Angeles, California 90024

Professor Grant Gill Smith
Department of Chemistry
College of Science
Utah State University
Logan, Utah 84322

Professor Walter Stoeckenius, M.D.
Cardiovascular Research Institute
School of Medicine
University of California
San Francisco, California 94143

Dr. Bernard Strehler
Department of Biology
University of Southern California
University Park
Los Angeles, California 90027

Professor H. Urey
Department of Geosciences
Laboratory of Organic Geochemistry
University of Arizona
Tucson, Arizona 85721

Dr. Frederick C. Wedler
Department of Biochemistry and Biophysics
Althouse Lab
Pennsylvania State University
University Park, Pennsylvania 16802

Mr. Fritz H. Woeller
Ames Research Center
Code LPD
Moffett Field, California 94035

Professor Carl R. Woese
Department of Genetics and Development
College of Liberal Arts and Sciences
University of Illinois
Urbana, Illinois 61801

Professor John H. Yopp
Department of Botany
Southern Illinois University
Carbondale, Illinois 62901

Professor G.U. Yuen
Department of Chemistry
Arizona State University
Tempe, Arizona 85281

National Aeronautics and
Space Administration

Washington, D.C.
20546

Official Business

Penalty for Private Use, \$300

THIRD-CLASS BULK RATE

Postage and Fees Paid
National Aeronautics and
Space Administration
NASA-451



NASA

POSTMASTER: If Undeliverable (Section 158
Postal Manual) Do Not Return
